Elimination of *Listeria monocytogenes* on Hotdogs by Infrared Surface Treatment

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ABSTRACT: The objective of this research was to develop an infrared pasteurization process with automatic temperature control for inactivation of surface-contaminated *Listeria monocytogenes* on ready-to-eat meats such as hotdogs. The pasteurization system contained 4 basic elements: an infrared emitter, a hotdog roller, an infrared sensor, and a temperature controller. The infrared sensor was used to monitor the surface temperature of hotdogs while the infrared emitter, modulated by a power controller, was used as a heating source. The surface temperature of hotdogs was increased to set points (70, 75, 80, or 85 °C), and maintained for bacterial kill. The infrared surface pasteurization was evaluated using hotdogs that were surface-inoculated with a 4-strain *L. monocytogenes* cocktail to an average initial inoculum of 7.32 log (CFU/g). On the average 1.0, 2.1, 3.0, or 5.3 log-reduction in *L. monocytogenes* was observed after the surface temperature of hotdogs was increased to 70, 75, 80, or 85 °C, respectively. Holding the sample temperature led to additional bacterial inactivation. With a 3 min holding at 80 °C or 2 min at 85 °C, a total of 6.4 or 6.7 logs of *L. monocytogenes* were inactivated. This study demonstrated that the infrared surface pasteurization was effective in inactivating *L. monocytogenes* in RTE meats.

Keywords: infrared heating, *L. monocytogenes,* RTE meats, surface pasteurization

Introduction

Listeria monocytogenes is a foodborne pathogen that compromises the safety of ready-to-eat (RTE) foods. Sporadic, yet large scale, foodborne illness outbreaks have been caused by contaminated RTE meats in the United States in recent years (CDC 1998, 2000, 2002). *L. monocytogenes* can cause severe illness or even fatalities among pregnant women, the elderly, persons with compromised immune systems, neonates, and fetuses. The mortality rate among this group can be as high as 20% (Mead and others 1999). Moreover, *L. monocytogenes* can grow at refrigerated temperature conditions, making it a serious public health concern (Ryser and Marth 1991). Responding to multiple outbreaks, the Food and Drug Administration (FDA) and the USDA Food Safety and Inspection Service (FSIS) imposed a "zero-tolerance" policy for *L. monocytogenes* in all RTE foods in 1989 (FDA/CFSAN 2003), which is still in effect. More recently, an interim final rule issued by USDA FSIS in 2003 requires RTE meat manufacturers to adopt postlethality intervention measures to effectively control and limit the risks posed by *L. monocytogenes* (Anonymous 2003).

Although raw meats and the ingredients added to produce RTE products may be contaminated with *L. monocytogenes*, a properly designed and executed thermal process or cooking step should completely eliminate the microorganism. However, the recontamination of cooked meats occurs in the postprocessing handling areas (conveying, peeling/decasing, cutting/slicing, and so on), and it is a major cause responsible for the outbreaks of foodborne listeriosis associated with RTE meats (Ryser and Marth 1991). Therefore, a postlethality intervention step, that is, a process designed to kill the contaminants after RTE meats are fully cooked, may become necessary to ensure the final microbial safety of the products. Since the contaminants are primarily located on the surfaces of products, an additional surface heat treatment may be sufficient to render the products free from *L. monocytogenes*.

Infrared is an invisible electromagnetic energy emitted from objects at high temperatures and can be absorbed by other objects at lower temperatures. The intense thermal energy from infrared emitting sources has been widely used in the industry for curing, heating, and drying of a variety of materials and products. In food processing, infrared heating, either used directly or in combination with air drying, has been used for drying or dehydration of various kinds of raw materials, including barley (Afzal and others 1999; Fasina and others 1999), rice paddy (Meeso and others 2007), carrot (Togrul 2006), onions and onion slices (Gabel and others 2006; Kumar and others 2006), potato (Afzal and Abe 1998), and apple slices (Nowak and Lewicki 2005). Infrared heating also has been used for cooking meat products such as hamburger patties (Sheridan and Shilton 1999) and baking biscuits (Wade 1987).

Since heating is one of the most effective technologies for inactivating foodborne pathogens, infrared heating also has been explored for pasteurizing foods to reduce or eliminate pathogens or other spoilage microorganisms. Tanaka and others (2007) investigated the suitability of using infrared heating for surface decontamination of strawberry. The authors applied a Monte Carlo method to simulate the process and used a thermographic camera to monitor the surface temperature of the strawberry samples. They reported that infrared heating achieved more uniform surface temperature distribution when it was compared with conventional air convection heating, but their estimation did not include microbiological testing to validate the simulation results. Gande and Muriana (2003) conducted a study that involved a radiant heat

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oven for prepackage pasteurization of various meat products. In that study, various meats, including turkey bologna, roast beef, corned beef, and ham, passed through a tunnel with heating coils. The treatment time varied from 60 to 120 s, and the air temperature ranged from 246 to 399 °C. Gande and Muriana (2003) reported that about 1.25 to 3.5 logs of *L. monocytogenes* were inactivated after the products were passed through the radiant oven. Huang (2004) developed an infrared surface pasteurization process using ceramic infrared heaters to treat turkey frankfurters. In that study, turkey frankfurters were allowed to rotate between 2 opposing infrared emitters maintained at a temperature of 545 ± 1 °C. The surface temperature of frankfurter samples was increased to an end point of 70, 75, or 80 °C. With an average initial inoculum of 10^6 to 10^7 CFU/cm^2, 3.5 to 4.5 logs reduction of *L. monocytogenes* were observed. The author also reported that discoloration of frankfurters occurred immediately following the infrared surface treatment. However, the color of the treated samples, measured by L^*, a^*, and b^*, was not significantly different from the untreated samples after refrigerated storage.

In the studies conducted by Huang (2004) or Gande and Muriana (2003), the surface temperature of frankfurters increased steadily during infrared surface treatment. The termination of the pasteurization process was either determined by the end point surface temperature of the products or by the residence time, which affected the final surface temperature. After the surface temperature reached the intended end point, the heating process must be terminated and the products must exit the infrared heating system, even though the bacteria may not have been completely eliminated from RTE meats. Otherwise, continued heating will cause detrimental changes to the products due to the intense infrared energy. In all these studies, there was no mechanism used to hold the product surface at a constant temperature in the infrared heating systems.

This study hypothesized that the effectiveness of the infrared surface pasteurization could be significantly improved with an additional holding process after the surface temperature of RTE meats was increased to its final temperature. Therefore, the objective of this research was to develop a new, single-step, infrared surface pasteurization process that could reliably control and maintain the surface temperature of RTE meats to prevent overheating and to achieve enhanced inactivation of *L. monocytogenes*.

Materials and Methods

Development of the infrared heating system

The infrared heating system was constructed with 4 basic elements: an infrared emitter, a hotdog roller, an infrared temperature sensor, and a PID (proportional-integral-derivative) power controller (Figure 1). A quartz tube infrared heating element (Model LFQ-1250-240V-L6, 245 × 120 mm, Mor Electric Heating Assoc. Inc., Comstock Park, Mich., U.S.A.) with a nominal rating of 1250 W at 240 V was used as an infrared emitting source. A countertop hotdog roller (Model 8023, Gold Medal Products Co., Cincinnati, Ohio, U.S.A.) was used as a platform to hold hotdogs for infrared heating. When in operation, the roller bars rotated at a speed of approximately 15 rpm, which provided a rotating mechanism for hotdogs to receive uniform infrared exposure during pasteurization. The quartz infrared emitter was installed 60 mm directly above the hotdog roller.

A calibrated infrared temperature sensor (SmartTRt/c^{TM}, Model 20-24V-420-100C, Exergen Corp., Watertown, Mass., U.S.A.) with a measurement range between 0 and 100 °C was used to measure and monitor the surface temperature of hotdogs during the surface pasteurization process. The infrared sensor had an aperture that produced a sensing area of 9.5 mm in diameter at 250 mm in the front. The spotting size was ideal for monitoring small objects such as hotdogs. The relatively long measuring distance (250 mm) prevented the sensor from being damaged by the infrared heating. Guided with a laser sighting device, the sensor was adjusted and positioned approximately 10° with respect to the horizontal surface of the hotdog roller such that the sensor had an unobstructed view across the surfaces of 2 hotdogs on the roller (Figure 1). This arrangement of the sensor allowed the measurement of the averaged surface temperature of 2 hotdogs being heated on the roller.

The analog signal (4 to 20 mA) from the infrared sensor was fed to the power controller (Model 2025-208-12P-X, Instrumental & Thermal Products Inc., Norristown, Pa., U.S.A.), which modulated the power input to the infrared heater. This was a closed-loop feedback temperature control system for automatically controlling the surface temperature of hotdogs. The process controller was manually tuned to minimize the come-up time, overshoot, and temperature fluctuations at set points. A type-K thermocouple was used

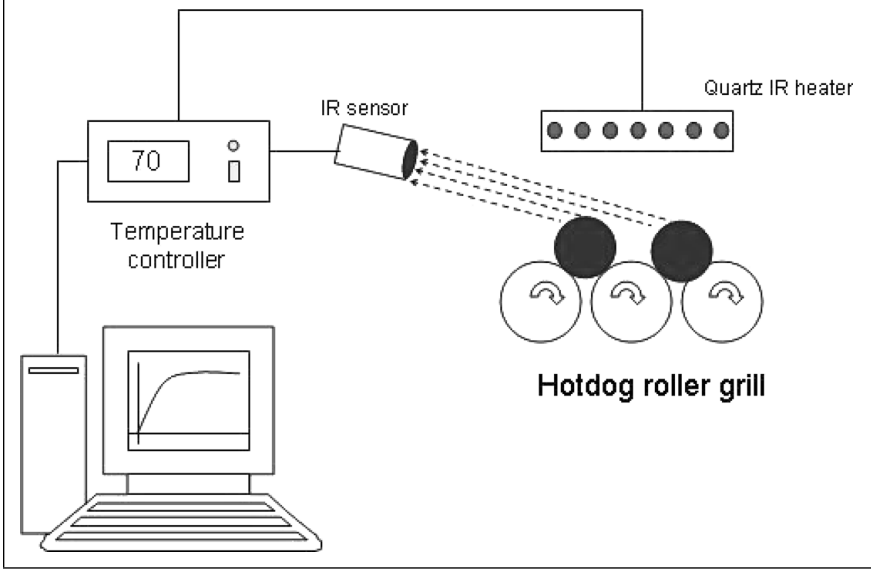

Figure 1—An infrared surface pasteurization system with feedback surface temperature control for inactivation of *L. monocytogenes* in RTE meats.

to monitor the temperature of the infrared emitter. The control process was monitored through a data-logging and communication tool (CALgrafix, Cal Controls Ltd., Brighton, U.K.) through a RS-232 interface of a Windows-based personal computer. The surface temperature of hotdogs and the temperature of the infrared emitter were simultaneously monitored and collected at 5-s intervals.

Surface heating process

Before an infrared heating process was initiated, a temperature set point (TSP) was entered into the controller. To prevent the loss of heat to the stainless steel roller bars and minimize the come-up time during the initial stage of the pasteurization process, the internal heating element of the hotdog roller was used to increase the surface temperature of the roller bars to ±2 °C of the TSP (empty load). Two pairs of thermocouples (Type T, Model TT-T-40-SLE, Omega Engineering Inc., Stamford, Conn., U.S.A.), loosely attached onto the surface of the roller bars, were used to monitor the surface temperature. The internal heating element was manually adjusted such that a minimum amount of heat was generated to maintain the surface temperature of the roller bars around TSP at empty load.

Once the surface temperature of the roller bars was stabilized at TSP, 2 hotdog samples were placed on the hotdog roller directly beneath the infrared heater. The heating was initiated, and the surface temperature of the hotdogs was allowed to increase and stabilize around the TSPs (70, 75, 80, or 85 °C). This was referred to as the heating process and the come-up period, and its duration was referred to as the come-up time (s). Depending on the lethality requirement, the surface pasteurization process might be continued by maintaining the surface temperature of the samples constant at the TSP until the desired lethal effect was achieved. This was referred to as the holding process, and its duration was referred to as the hold time (s).

The infrared surface heating was terminated by quickly removing the hotdogs from the roller bars and immediately placing them into separate filter stomach bags (190 × 300 mm, Nasco Whirl-Pak®, Fort Atkinson, Wis., U.S.A.), each containing 100 mL ice-cold (approximately 5 °C) sterile 0.1% peptone water (PW, BD/Difco Laboratories, Sparks, Md., U.S.A.). After each run, the hotdog roller surfaces were cleaned and disinfected with a 70% ethanol solution. The infrared emitter was allowed to cool below 50 °C before the next run was initiated. Each heating process was replicated at least 3 times.

Bacteria strains

Four strains of *Listeria monocytogenes* (H7763, H7776, H7778, and 46877), isolated from actual listeriosis outbreaks associated with ready-to-eat meats, were obtained from the culture collection of USDA ARS Eastern Regional Center located at Wyndmoor, Pa., U.S.A. The bacteria were regularly propagated and maintained on tryptic soy agar (TSA, BD/Difco Laboratories) plates and stored at 4 °C.

To prepare the bacteria cultures for use in the surface inoculation of hotdogs, each strain was grown individually in 10 mL brain heart infusion broth (BHI broth, BD/Difco Laboratories) at 37 °C and was harvested after approximately 22 to 24 h of incubation. The bacteria cultures were centrifuged at 2400 × *g* for 15 min in a refrigerated centrifuge, washed once with 10 mL PW, recentrifuged, and resuspended in 1 mL PW. The 1 mL culture cells were combined to form a cocktail with a concentration about $10^{9.5}$ CFU/mL of *L. monocytogenes*.

Sample preparation and inoculation

Generic brand beef hotdogs were purchased from a local manufacturer. The hotdogs, each approximately 130 mm in length and 22 mm in diameter, were packed in 5 lb (2.27 kg) packages. The hotdog packages were maintained in a deep freezer (−70 °C) and were used within 4 mo. Each package was thawed overnight in a refrigerator (approximately 4 °C). After thawing, the average weight of a hotdog was 43 g. Before inoculation, the hotdogs were dried with paper towels to remove the exudates produced during thawing. A small volume (50 μL) of bacterial cocktail was applied and spread onto the surface of each hotdog. The inoculated hotdogs were immediately subjected to the infrared surface pasteurization process using the procedures described previously.

Determination of bacterial counts

The entire hotdog in a filter bag was used to determine the number of survivors after pasteurization. The hotdog sample was homogenized using a stomacher (Seward Stomacher® 400 Circulator, Seward Co., Norfolk, U.K.) operated at 260 rpm for 3 min. After homogenization, the sample was either directly used for plating or serially diluted with PW. Freshly prepared PALCAM *Listeria* selective agar (BD/Difco Laboratories) plates (Van Netten and others 1989) were used to recover the cells of *L. monocytogenes*. The plates remained at room temperature for about 2 h to allow the resuscitation of the thermally injured cells of *L. monocytogenes* before being placed into an incubator. The PALCAM plates were incubated at 37 °C for approximately 48 h. Typical *Listeria* colonies were counted and converted to the logarithm (base 10) of CFU/g of hotdogs.

Results and Discussion

Surface heating of hotdogs

The average surface temperature of hotdogs immediately before the infrared surface heating was initiated, as measured by the infrared sensor and confirmed by a thermocouple, was 12.7 ± 0.2 °C (mean ± standard error) for all the samples tested in this study. As the samples were exposed to infrared heating, the surface temperature started to increase steadily in the come-up period (Figure 2) when full power (100%) was supplied to the infrared emitter. Since a feedback control mechanism was used to control the heating process, the electric power was gradually reduced as the surface temperature of the hotdogs approached the set points. At the end of the come-up period, approximately 3 to 5 °C of overshooting occurred, but the surface temperature quickly stabilized around the set points for the process. During holding, the average surface temperature of samples (data not shown) was almost identical to the perspective set point with relatively small standard deviations (1.0 to 1.5 °C).

The temperature of the infrared emitter did not increase immediately after the heating process was initiated. There was an approximately 30-s delay before a significant increase in the temperature of the infrared emitter was observed. Since the surface temperature of hotdogs was lower than the temperature of the ambient, the roller bars, and the infrared emitter, it began to increase as soon as the heating was initiated. During the come-up period, the surface temperature increased at an average of 0.46 ± 0.01 °C/s, (mean ± SE) or 27.6 °C/min, measured from all 86 temperature–time history curves. Since the initial surface temperature (12.7 °C) of samples was relatively constant, the come-up time was basically determined by the TSP of a process. The average come-up time was 137 ± 3, 140 ± 5, 150 ± 4, 155 ± 4, and 162 ± 7 s (mean ± SE) for

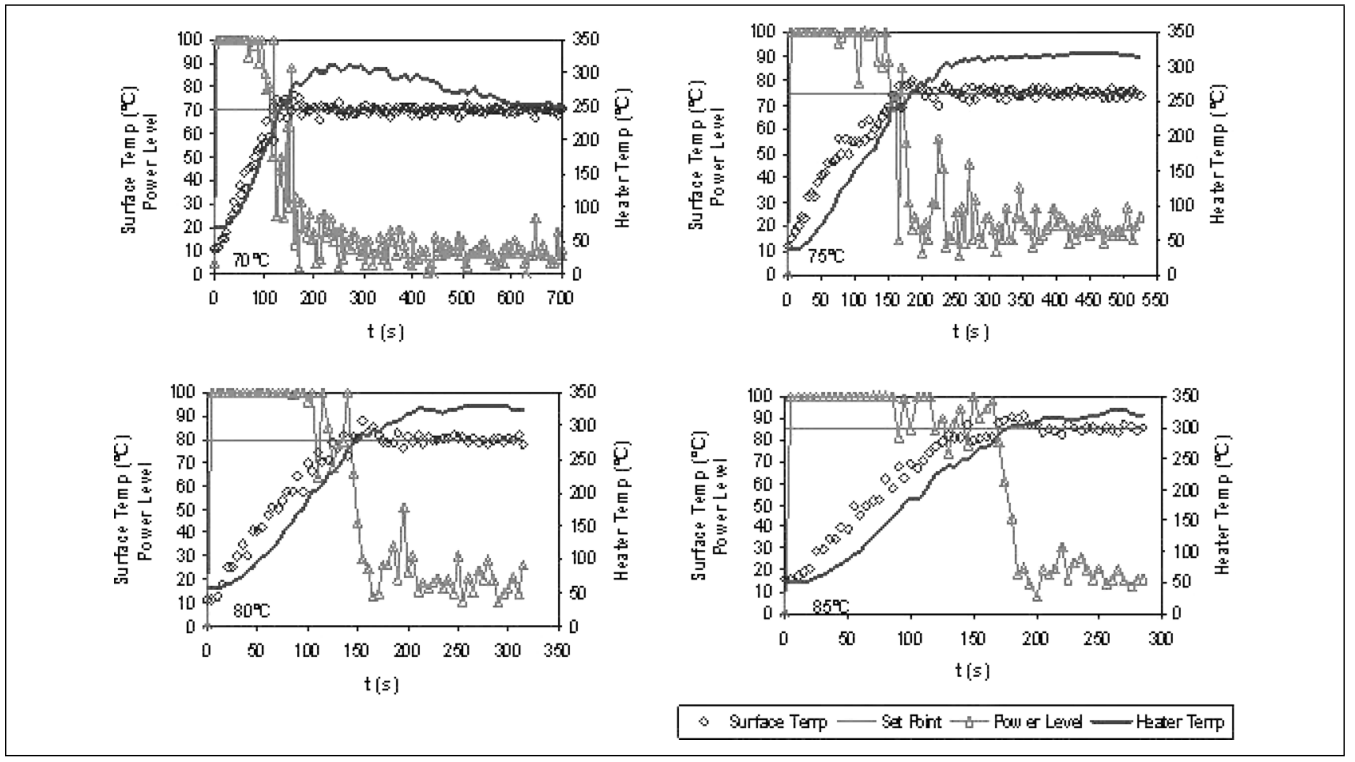

Figure 2—Temperature profiles of the hotdog surface and infrared emitter and the percentage of power supply to the heater during surface pasteurization processes.

the TSPs of 70, 75, 80, and 85 °C, respectively. Since the infrared emitter was allowed to cool below 50 °C before the beginning of each heating process, the come-up time was relatively long (2.3 to 2.7 min).

The long come-up time observed in this study was probably caused by the relatively low temperature reached in the infrared emitter. During the surface pasteurization process, the infrared emitter gradually warmed up. Because the heating process was controlled by the difference between the surface temperature of the samples and the target final TSP, the temperature of the infrared emitter stabilized around 310 to 320 °C, depending on the final temperature of the hotdog surface. In all tests, the infrared emitter never exceeded 330 °C although the quartz infrared emitter could be heated to a much higher temperature (>800 °C). According to Wien's displacement law (Knudsen and others 1984), the infrared waves generated from the infrared emitter would be longer than 4.8 μm. The infrared waves emitted from the quartz emitter would range from far infrared to mid infrared (5 to 350 μm).

The temperature of the infrared emitter used in this study was substantially lower than that used in other studies conducted by Huang (2004), in which the infrared emitter was maintained constant at 545 °C. The surface temperature of turkey frankfurters was allowed to increase from around 10 °C to a final temperature of 70, 75, and 80 °C. As a result of the higher temperature in the infrared emitter, the come-up time was substantially shorter (82 to 103 s) in the study reported by Huang (2004). Therefore, increasing the initial and final temperatures of the infrared emitter may substantially reduce the come-up time, which can be achieved by proper sizing of the infrared emitter. The rated capacity of the infrared emitter was 1250 W, which is probably too large for heating 2 hotdogs. The power generated by the infrared emitter was sufficient to increase the surface temperature of hotdogs to the final set point before it reached its full capacity.

Infrared surface pasteurization

The average initial bacterial concentration was 7.32 ± 0.03 log (CFU/g) on the hotdog samples. Different degrees of bacterial reduction were observed as the hotdogs were exposed to the infrared heating (Figure 3). As the surface temperature of the hotdogs was increased to 70, 75, 80, or 85 °C, approximately 1.0, 2.1, 3.0, or 5.3 logs of bacteria, respectively, were killed during the initial come-up period. As usual in a thermal process, the inactivation of *L. monocytogenes* was affected by both the final surface temperature of hotdogs and the hold time, and the impact of temperature seemed to be more significant on the bacterial kill. During the come-up

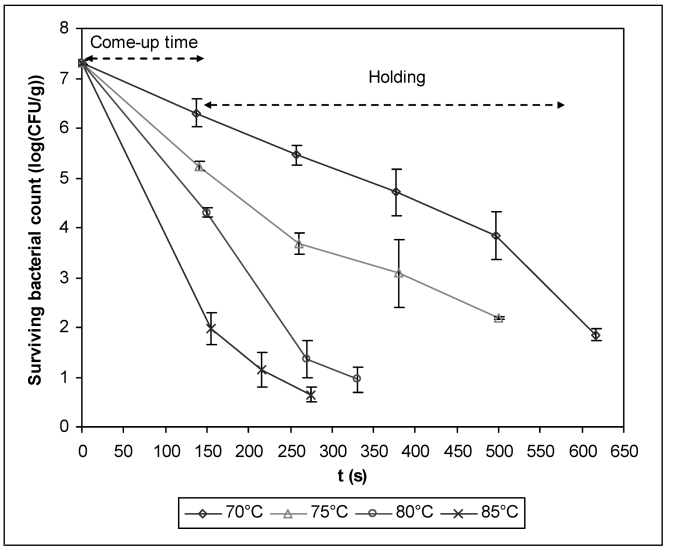

Figure 3—The survival of *L. monocytogenes* in hotdogs observed during infrared surface pasteurization processes.

period, an average of 18 s was needed to increase the final surface TSP of the hotdogs from 70 to 85 °C, but on average an additional 4.3 logs of bacteria were inactivated in the test samples.

The combination of time and temperature is critical in infrared surface pasteurization, as it is in all thermal processes. Without an additional holding period after come-up period, it was impossible to kill all bacteria if the original level of contamination was high. In the studies previously conducted by Gande and Muriana (2003) where the infrared emitting source was held at constant temperatures and no holding was used, 1.25 to 3.5 logs in the reduction of bacterial counts were reported. For turkey frankfurters, 3.5 to 4.5 log-reductions were reported by Huang (2004). Similar results were observed in this study. With an average initial inoculum of 7.32 log (CFU/g), only 1 to 5.3 logs of *L. monocytogenes* were inactivated in hotdogs after the surface temperature was increased to 70 to 85 °C.

The relatively low number of bacterial inactivation during the come-up period can be attributed to the slow heat transfer process and the distribution of bacteria in the products. Since *L. monocytogenes* cells were never completely located on the surfaces of meat products, some bacteria were harbored in the cavities and crevices under the surfaces. Heat must be transferred by conduction to these areas. Since conduction heat transfer is by nature a slow process, the temperature in the areas beneath the surfaces of the meat products may not be lethal to the bacteria even if the surface temperature may have been very high at the end of the come-up period. As a result, some bacteria may survive and potentially present a risk to the consumer.

Since the temperature of the hotdog surfaces was effectively controlled by the feedback control mechanism during the infrared pasteurization process, overcooking and burning of the hotdogs was prevented. The holding period contributed to additional bacterial destruction in the hotdog samples (Figure 3). With 3-min holding at 80 °C or 2 min at 85 °C, a total of 6.4 or 6.7 logs of *L. monocytogenes* were inactivated. With 8-min holding at 70 °C, a total of 5.5 logs of bacteria were inactivated in the hotdog samples during infrared surface pasteurization. With longer hold time, it is possible to eliminate all *L. monocytogenes* from hotdogs.

According to a survey conducted by Gombas and others (2003), the level of contamination of *L. monocytogenes* in RTE meats can be as high as 10^3 to 10^4 CFU/g. The infrared surface pasteurization process with temperature holding can provide ample lethal power to kill all *L. monocytogenes* should a higher level of contamination occur. The quality of infrared-treated product is more of a concern to both manufacturers and consumers. Similar to the previous study reported by Huang (2004), the color of the infrared treated hotdogs in this study was slightly browner, by visual observation, than the untreated samples. Since it was determined in the previous studies that the color of the infrared-treated turkey frankfurters would return to normal after refrigerated storage, and there was no significant change in the color attributes (L^*, a^*, and b^*), no colorimetric determination was conducted in this study. However, more research is needed in the future to evaluate the effect of infrared heating on the color of products.

Conclusions

This study successfully demonstrated the feasibility of using a feedback control mechanism to control the process of infrared surface pasteurization of inoculated hotdogs. The experimental results showed that it was possible to first increase the surface temperature of hotdogs to a predetermined final target temperature and then hold the surface temperature steady for an extended period of time until a desirable lethality was achieved. In general, a higher surface temperature, in combination with a hold time, was more effective in inactivating *L. monocytogenes* in hotdogs. Depending on the final surface temperature and the hold time, more than 5 logs of bacteria were destroyed at the end of the infrared surface pasteurization. In all experiments, it was observed that the temperature of the infrared emitter was below 330 °C, which can be easily achieved in the food industry. Although hotdogs were used in the experiments to demonstrate the concept of an automatically controlled infrared surface pasteurization process, this technology can be used to treat any RTE meats in the food industry.

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References

Afzal TM, Abe T. 1998. Diffusion in potato during far infrared radiation drying. J Food Eng 37:353–65.
Afzal TM, Abe T, Hikida Y. 1999. Energy and quality aspects during FIR-convection drying of barley. J Food Eng 42:177–82.
Anonymous. 2003. Control of *Listeria monocytogenes* in ready-to-eat meat and poultry products; Final Rule. Fed Reg, June 5, 2003, Volume 68, No. 109. Washington, D.C.
[CDC] Centers for Disease Control and Prevention. 1998. Multistate outbreaks of listeriosis—United States. Morb Mort Wkly Rep 47:1085–6.
[CDC] Centers for Disease Control and Prevention. 2000. Multistate outbreaks of listeriosis—United States. Morb Mort Wkly Rep 49:1129–30.
[CDC] Centers for Disease Control and Prevention. 2002. Public health dispatch: outbreaks of listeriosis—northeastern United States. Morb Mort Wkly Rep 51: 950–1.
Fasina OO, Tyler RT, Pickard MD, Zheng GH. 1999. Infrared heating of hulless and pearled barley J. Food Process Pres 23:135–51.
[FDA/CFSAN] Food and Drug Administration/Center for Food Safety and Applied Nutrition. 2003. Quantitative assessment of relative risk to public health from foodborne *Listeria monocytogenes* among selected categories of ready-to-eat foods. Washington, D.C.: Food and Drug Administration.
Gabel MM, Pan Z, Amaratunga KSP, Harris LJ, Thompson JF. 2006. Catalytic infrared dehydration of onions. J Food Sci 71:E351–7.
Gande N, Murina P. 2003. Prepackage surface pasteurization of ready-to-eat meats with a radiant heat oven for reduction of *Listeria monocytogenes*. J Food Prot 66:1623–30.
Gombas DE, Chen Y, Clavero RS, Scott VN. 2003. Survey of *Listeria monocytogenes* in ready-to-eat foods. J. Food Prot 66:559–9.
Huang L. 2004. Infrared surface pasteurization of turkey frankfurters. Innov Food Sci Emerg Tech 5:345–51.
Knudsen JG, Bell KJ, Holt AD, Hottel HC, Sarofim AF, Standiford FC, Stuhlbarg D, Uhl VW. 1984. Heat transmission. In: Perry RH, Green S, Maloney JO, editors. Perry's chemical engineers' handbook. 16th ed. New York: McGraw-Hill Inc.
Kumar DGP, Kumar H, Hebbar U, Ramesh MN. 2006. Suitability of thin layer models for infrared-hot air-drying of onion slices. LWT—Food Sci Tech 39:700–5.
Mead PS, Slutsker L, Dietz V, McCraig LF, Bresee S, Shapiro C, Griffin P, Tauxe RV. 1999. Food-related illness and death in the United States. Emerg Infect Dis 5:607–25.
Meeso N, Nathakaranakule A, Madhiyanon T, Soponronnarit S. 2007. Modeling of far-infrared irradiation in paddy drying process. J Food Eng 78:1248–58.
Nowak D, Lewicki PP. 2005. Quality of infrared dried apple slices. Dry Tech 23:831–46.
Ryser ET, Marth ET. 1991. *Listeria,* listeriosis, and food safety. New York: Marcel Dekker Inc.
Shridan P, Shilton N. 1999. Application of far infra-red radiation to cooking of meat products. J Food Eng 41:203–8.
Tanaka F, Verboven P, Scheerlinck N, Morita K, Iwasaki K, Nicolai B. 2007. Investigation of far infrared radiation heating as an alternative technique for surface decontamination of strawberry. J Food Eng 79:445–52.
Togrul H. 2006. Suitable drying model for infrared drying of carrot. J Food Eng 77:610–9.
Van Netten P, Perales J, Van Moosdijk A, Curtis GDQ, Mossel DAA. 1989. Liquid and solid selective differential media for the detection and enumeration of *Listeria monocytogenes* and other *Listeria* spp. Int J Food Micro 8:299–316.
Wade P. 1987. Biscuit baking by near-infrared radiation. J Food Eng 6:165–75.